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Trends and racial differences in infant mortality in South Africa

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Abstract

Racial differences in infant mortality in South Africa are studied using household-level data from 1987 to 1989 and 1998. Logistic regression models are estimated to explore the determinants of the overall trend in infant mortality and racial disparities in infants' survival chances. We do not find evidence for reduced overall risk of infant death among births that occurred from 1993 to 1998 when compared to those that occurred from 1982 to 1989, despite policy and action directed toward this goal by the new government that was elected in early 1994. We also find that persistent inequalities in the personal and household resources of South Africa's four main racial groups substantially account for racial differences in infant survival rates in both periods. These findings are discussed in light of contemporary social and health issues in South Africa.

Keywords: South Africa; Infant mortality; Apartheid; Racial inequality

Introduction

Population health in South Africa has been deeply influenced by the institutionalized racial discrimination that prevailed for much of recent history and led to dramatic disparities in morbidity and mortality. However, the dismantling of the *apartheid* system in 1994 held great potential for reducing racial disparities in health. The introduction of large-scale social programs, including the implementation of better sanitation and infrastructure in poor areas and free medical care for pregnant women and young children, was an effort to reduce the prevalence of many of the major risk factors for death in infancy and childhood. Nonetheless, the first democratically elected government in South Africa inherited a stagnant economy, an exceptionally high level of poverty, and a population with major inequities in access to the basic resources necessary for health. If major developmental shifts in South Africa have been successful in combating existing conditions in the short term, we would expect progressive reductions in mortality from the traditional "diseases of poverty," such as diarrhea and respiratory infections, which account for a large proportion of infant deaths in South Africa. In this analysis we examine trends in overall infant mortality, a measure sensitive to changes in level of living, assessing changes in overall levels and racial differences from the mid-1980s to the late-1990s. Central social background forces that are likely to affect trends in overall infant mortality risk over the period we study include the persistence of *apartheid*-era racial residential segregation, migrant labor patterns, separate

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and unequal provision of health care services, and the maintenance of socioeconomic inequality.

It is important to understand the social context and existing disparities in infant mortality just before HIV/AIDS began to compete with the classic early childhood diseases of poverty. Model-based estimates generated by the Actuarial Society of South Africa (Dorrington, Bradshaw, & Budlender, 2002) show that increases in infant mortality that could be attributable to the complex of factors surrounding the HIV/AIDS epidemic had only begun to appear at the conclusion of the period we consider here. However, recent evidence suggests that the brunt of the epidemic is being borne by those who traditionally have had the highest rates of mortality: the poor, Nonwhites, and those living in marginalized informal settlements (Brookes, Shisana, & Richter, 2004). This suggests that hierarchies of disadvantage will be preserved or exacerbated by HIV/AIDS, not reversed. At the close of the paper, we return to this issue to situate our findings in a discussion of the progress of the HIV/AIDS epidemic since the late 1990s, and comment on the likely implications.

Measuring the impact of emerging disease is difficult if trends in the preceding period are not understood. In this analysis, we are able to compare data from nationally representative household surveys collected in the late *apartheid* and early post-*apartheid* eras; this represents an advance because most other individual-level data available for this period excluded the nominally independent "TVBC States" that were home to about a quarter of the Black population, and vital events data have traditionally been poor for Nonwhites (Botha & Bradshaw, 1985).[1] Collected mainly for demographic purposes, these household data cannot be used to investigate changes in the cause-of-death structure in South Africa, but can provide insight into the impact of social and structural background factors that continue to shape health and health disparities as new challenges to public health arise. In this analysis we argue that policies of separate development that disadvantaged Nonwhites under *apartheid* created inequalities in the level of living that help to explain the large racial differences in infant survival in South Africa both at the end of *apartheid* and in the early years of South Africa's new dispensation.

Racial inequality and infant survival in South Africa

Racial inequality in South Africa was imposed by White settlers in the 17th century and institutionalized, codified, and reinforced when the National Party gained power in 1948. Under the *apartheid* system, "Whites" (10% of the population in 2001), "Asians" (mainly from the Indian subcontinent) (2%), "Coloreds" (mixed-race people) (9%), and "Blacks" (the indigenous Bantu-speaking population) (79%) were separated into four official population groups, and virtually all life chances were determined on the basis of group membership (Statistics South Africa, 2003). Racial disparities in health were strongly shaped by residential segregation by race (Louw, Khan, Woods, Power, & Thompson, 1995; Rip, Bourne, & Woods, 1989a, b; Rip, Keen, & Kibel, 1986), and the development of a migrant labor system (Ramphele & Heap, 1991). Earlier in the 20th century, some 13% of the land area of South Africa had been designated as Black "homelands," and during the 1960s and 1970s $3\frac{1}{2}$ million Blacks were "removed" from the cities to these nominal homelands, often places where neither they nor their ancestors had lived (Davenport, 1987; Kaufman, 1998; Platzky & Walker, 1985). The rural areas of the homelands were extremely economically marginalized, and a migrant labor system developed as residents commuted long distances to work in "White" South Africa.

Provision of health care was extremely unequal under *apartheid*, distributed separately by population group and residential area (Bloom & McIntyre, 1998). The system allocated resources unequally by race, with central cities in "White areas" featuring sophisticated curative services rivaling those available in developed countries, while women living in homeland areas were often forced to travel great distances to visit a clinic providing only basic services (Abrahams, Jewkes, & Mvo, 2001; Bloom & McIntyre, 1998). One study reported that among women reporting for the first time to prenatal clinics in rural areas of northern KwaZulu, 41% had had their last previous birth at home (Buchmann, Crofton Briggs, & McIntyre, 1992). Health services were not the only infrastructures that were unequally distributed under *apartheid*; environmental exposure at the household level, particularly the quality of household sanitation, also influences mortality risk. Clean running water and adequate plumbing reduce the likelihood of gastrointestinal diseases that are particularly dangerous for children living in fragile conditions (Bachmann, London, & Barron, 1996), but toward the end of and subsequent to the *apartheid* period, many Blacks migrated as families to the cities, setting up squatter communities lacking plumbing and electricity. These communities may not represent an improvement in environmental conditions over the homeland areas, and may be worse in some respects.

Educational and occupational opportunities were also separate and unequal under *apartheid* (Molteno & Kibel, 1989) and wide disparities in income were maintained (Treiman, McKeever, & Fodor, 1996).

[1] A recent study of infant mortality and birth registration data showed that completeness of birth registration ranged from 10% in the Eastern Cape, North West and Northern Provinces to 60% in the Western Cape (Nannan, Bradshaw, Mazur, & Maphumulo, 1998).

While South Africa ranks as a middle-income country with a gross domestic product of US $8900 in 1999 dollars (World Bank, 2000), inequality in the distribution of socioeconomic resources is extreme (Statistics South Africa, 2000). At the end of *apartheid* 53% of South African children lived in poor households (according to the World Bank's definition), the majority of whom were Black and living in rural areas (National Institute for Economic Policy, 1996).

Taken together, these policies of separate and unequal development under *apartheid* resulted in the coexistence of distinct mortality profiles by population group, with Black and Colored children especially susceptible to diseases of poverty (Andersson & Marks, 1988; Bachmann et al., 1996; Bourne, Rip, & Woods, 1988; Haffejee, 1995; Molteno, Ress, & Kibel, 1989). Studies across South Africa also show significantly higher risk for Nonwhite infants and children, particularly Blacks, in the 1970s and 1980s (Ramphele & Heap, 1991; Rip et al., 1989a). One study found that the infant mortality rate (IMR) for Coloreds declined from 135 deaths per 1000 live births to 51 over the period from 1970 to 1983, while for Whites it dropped from 22 to 13 (Herman & Wyndham, 1985). Among Blacks in some urban areas, the IMR fell from 124 to 86 from 1970 to 1980, but the IMR was still 130 in the rural Transkei area in 1980 (Herman & Wyndham, 1985). Another study of rural Blacks in the northern Transvaal area found an IMR of 88, with no significant change over the period from 1976 to 1986, in contrast to documented decreases in other racial groups (Koumans, 1992). The Medical Research Council of South Africa reported child mortality rates of between 115 and 120 at the end of *apartheid*, considerably higher than the worldwide average of about 34 deaths per 1000 live births (National Institute for Economic Policy, 1996; SAIRR, 1995). The rate for Black children was about six times higher than the rate for Whites (SAIRR, 1996).

Since the end of *apartheid* in 1994, the South African government has made considerable efforts to reduce these dramatic disparities, including establishing the National Programme of Action (NPA) to implement a "call for children" commitment, providing free medical care for pregnant women and children under 7 years of age, and establishing a family and children section within the Ministry of Welfare, a National Youth Commission, and the Nelson Mandela Children's Fund (Lockhat & Van Niekerk, 2000). A plan introduced by the new government supports health for all South Africans, in the form of an expanded primary care-based system funded by economic growth. Between 1994 and 1996, more than 100,000 homes, 400 clinics and 4750 health posts were newly built or under construction (Benetar et al., 1997). Despite all of these positive developments, however, some have argued that because of a poorer economic climate since the end of *apartheid* and the persistence of the inequalities sustained under that regime, children may actually be worse off than before (Desmond, 1998; Ramashia, 1998). The expansion of primary health care has severely strained existing health services, reducing their efficacy (Haffejee, 1995). In addition, changes since the end of *apartheid* have required severe budget cuts in historically better-served provinces to create parity with the less well-served areas, reducing the overall effectiveness of the existing health care institutions (Benetar et al., 1997). There is evidence that racial group disparities in mortality have persisted beyond the *apartheid* period, despite an overall secular decline in the IMR (Duncan, 1997).

Given historical conditions, under *apartheid* the risk of infant mortality followed the entrenched gradient of privilege, lowest for Whites and higher for Asians and Coloreds, with Black infants most vulnerable. Despite the introduction and implementation of policies to address disparities, long-standing conditions were so unequal that we expect the same mortality gradient in the years following the official end of *apartheid*. We further expect that household socioeconomic conditions, including mother's education, household wealth and the quality of the water supply, will be independently associated with infant survival and will at least partly explain the racial disparities in both periods. Given the enormity of the challenges facing the new South African government, we expect only a minor reduction in the overall infant mortality rate.

Data and methods

Data

We utilize data from the 1987–1989 and 1998 South Africa Demographic and Health Surveys (SADHS), nationally representative surveys of women 15–49 years old that include detailed information about all births in the previous 5 years. Despite the shortcomings inherent in retrospective designs (particularly underreporting of infant deaths and births and misreporting of age at death), in the absence of an adequate vital registration system these data provide the best estimates of infant mortality available for South Africa. Descriptive statistics from both surveys are included in the main report on the 1998 Survey (Department of Health of South Africa and Macro International (SADOH and MI), 2003), but these figures do not adjust for sociodemographic differences across the population, a focus of the present analysis.

The SADHS conducted from 1987 to 1989 during the late *apartheid* era was implemented by the Human Sciences Research Council (HSRC) of South Africa, modeled on the USAID/Macro International DHS studies in other parts of the world. The SADHS received

no assistance from these organizations or the demographic community because of international sanctions against *apartheid* (Kaufman, 1997, 1998). Though there were some problems during data collection, this is the sole source of information from the period about women from all race groups and across all areas of South Africa. The full sample consists of nearly 22,000 women aged 12–49 years who were currently in a union or living with someone, had been in a union or living with someone previously, or had ever given birth or were currently pregnant. After restricting the sample to women 15–49 years of age (to be consistent with the age range of the 1998 DHS) who had had a birth in the previous 5 years and were not missing information on their race, we arrived at an analytic sample of 14,902 births. Twins and higher multiple births are omitted from the analysis because they have poorer survival probabilities and differ in other ways from singletons. The 1998 SADHS was conducted in 1998, utilizing conventional survey procedures and with technical assistance from Measure DHS (formerly Macro International) (SADOH and MI, 2003). The 1998 SADHS used a multistage, clustered sampling frame based on that used for the 1996 South African census, and includes information about 4891 singleton births.

When considering the comparability of the two data sources, it is important to note that the 1987–89 SADHS was not conducted under ideal conditions (Caldwell & Caldwell, 1993). Interviews were carried out during a period of considerable political unrest, so the data may more adequately represent the areas that were least dangerous at that time and which also may have had relatively lower rates of infant mortality. Also, separate surveys were conducted in each of the 10 homelands and, within "White" South Africa, separate surveys were conducted of each of the four race groups; the questionnaires were not translated into all of the major languages; and the sample design, training, and fieldwork were not well documented (Kaufman, 1997). Nonetheless, quality checks indicate that distributions of characteristics of each racial group in the pooled (national) sample are consistent with expectation, and sampling design and fieldwork difficulties probably did not introduce substantial bias into the sample (Caldwell & Caldwell, 1993). If anything, the 1987–89 SADHS may suffer from some underreporting of infant deaths by Nonwhites, which would cause us to underestimate any decreasing trend in mortality between 1987 and 1998. However, there is no reason to believe that the 1998 survey conditions eliminated all potential sources of underreporting; a recent study suggested that racial differences in vital events reporting are still dramatic in contemporary South Africa (Nannan, Bradshaw, Mazur, & Maphumulo, 1998).

Our outcome measure is whether a child born within the 5 years prior to each survey died in the first year of life, based on the mother's report.[2] National infant mortality rates decreased from around 60 in the late 1970s to about 40 in 1991, but appear to have increased slightly since then (SADOH and MI, 2003, Fig. 6.1). The reasons for this reversal are considered below.

Explanatory variables

Characteristics of children, their mothers, and their households are displayed in Table 1, which shows the percentage in each category for categorical variables and means and standard deviations for continuous variables. Figures are presented separately for Black, Colored, Asian, and White children to document the disparities in resources that characterize these groups in South Africa. Mother's race is the key independent predictor of child mortality in this analysis because, as discussed above, race is the major axis of differential advantage in South Africa.

Measured child's characteristics include sex, because there is some evidence that in South Africa male infants and children have a higher mortality risk than do females (Koumans, 1992). We measure birth order and the length of the preceding birth interval with a single categorical variable. First births occur to mothers with presumably little experience at caring for infants, which increases the risk of mortality, while second and higher-order births occur to women who presumably have more familiarity with child care, which decreases the risk of mortality. However, they may also have fewer resources for the new child, which increases the risk. Also, the demographic literature has established that children born after a relatively short interval are at greater risk of mortality than those spaced further apart (Sastry, 1997); we distinguished children born within 36 months of a sibling from those born further apart. The modal category across racial groups and survey years is first births, but there were significant differences in the samples for 1987–89 and 1998 for Black and Colored births, with Black births less likely to be first-order and Black and Colored births more likely to have long preceding intervals in the latter survey.

Older mothers are at highest risk for birth complications (Pebley & Stupp, 1987); we distinguish mothers who were 35 years of age or older at the time of the birth. Older mothers were more common for Black and

[2]Our data lack information about women who died in the five years preceding the surveys. The children of these women probably have the highest rates of infant mortality. However, even among Blacks, mortality rates for women aged 15–49 are relatively low, and probably have little impact on our results. Insofar as there is any impact, it should bias our estimates of racial differences in a conservative direction since Black women have poorer health profiles than others, on average, and the children of women who died probably would experience higher than normal rates of mortality.

Table 1
Summary statistics for individual and community variables used in statistical analysis of infant mortality by mother's race, South Africa demographic and health-style surveys 1987–89 and 1998

	Black/African			Colored			Asian			White		
Variable	1987–89	1998	Test[a]	1987–89	1998	Test	1987–89	1998	Test	1987–89	1998	Test
Child's sex male (%)	50.6	50.4	0.922	51.0	50.8	0.818	50.1	46.0	0.980	49.7	51.3	0.856
Birth order/length of preceding birth interval (%)												
First birth	40.7	32.9	<0.001	35.4	35.2	<0.001	39.3	36.5	0.246	36.1	39.9	0.324
Second birth, ⩽36 months	10.1	7.31		10.1	5.88		17.7	15.5		20.7	22.0	
Second birth, >36 months	12.5	16.1		17.5	26.9		12.2	18.7		15.0	15.3	
Third+birth, ⩽36 months	18.3	16.5		12.9	8.21		11.2	11.8		12.7	10.6	
Third+birth, >36 months	18.1	27.2		23.1	23.8		18.4	17.4		15.4	12.2	
Missing	0.33	0.00		1.00	0.00		1.24	0.00		0.17	0.00	
% Mother 35 years+at birth	14.4	24.3	<0.001	16.8	20.2	0.037	12.5	15.9	0.756	13.8	15.4	0.701
Mother's years education	7.07	7.88	<0.001	6.98	8.50	<0.001	9.76	11.1	<0.001	12.4	12.6	0.189
	(3.71)	(3.98)		(3.30)	(3.21)		(2.61)	(2.40)		(2.45)	(2.35)	
Household wealth	0.279	0.474	<0.001	0.602	0.762	<0.001	0.966	0.955	0.296	0.984	0.945	0.005
	(0.329)	(0.378)		(0.405)	(0.320)		(0.131)	(0.125)		(0.086)	(0.136)	
Mother's residence: childhood and current (%)												
Lifetime urban	29.6	24.6	<0.001	68.3	64.5	<0.001	89.2	89	<0.001	76.7	78.2	0.339
Rural-to-urban migrant	7.04	18.3		3.74	11.7		1.99	11.0		6.41	5.77	
Urban-to-rural migrant	2.59	2.81		2.01	5.38		4.93	0.00		10.6	11.4	
Lifetime rural	60.8	53.2		26	17.6		3.85	0.00		6.24	4.65	
Missing	0.00	1.12		0.0	0.82		0.00	0.00		0.00	0.00	
Household sanitation (%)												
No clean water, no toilet	9.73	13.4	<0.001	3.47	1.41	0.032	0.00	0.00	<0.001	0.00	0.00	0.002
Clean water, no toilet	5.53	5.64		4.65	2.90		0.00	0.00		0.00	0.00	
No clean water, have toilet	25.1	12.7		3.92	1.12		1.37	0.00		3.04	0.97	
Clean water, have toilet	59.7	65.1		88.0	93.8		98.6	98.3		97.0	97.3	
Missing	0.00	3.22		0.00	0.760		0.00	1.71		0.00	1.75	
Number of births	12,424	3,996		1,097	579		788	108		593	208	
Number of deaths	524	171		33	18		13	1		3	3	

[a]Tests for difference conducted using χ^2 tests for categorical variables and t-tests for continuous variables.

Colored births than for Asian or White births, and the proportion of older mothers was significantly larger in the 1998 survey than the 1987–89 survey for Black and Colored children. Mother's education, a key indicator of household socioeconomic standing, is also a strong predictor of infant mortality. More educated women may have better access to health-related information and may be more efficient at using the resources they have to raise healthy children (Cleland, 1990; Cleland & Van Ginneken, 1988). We measure mother's education by the number of years of schooling. In the 1987–89 sample, Colored and Black mothers had an average of about 7 years of schooling, compared to 9.8 years among Asian mothers and 12.4 years among White mothers. Average educational attainment was significantly higher in the 1998 sample for all groups except Whites, with averages of 7.9 years, 8.5 years, 11.1 years, and 12.6 years for Black, Colored, Asian, and White mothers, respectively.

A household's economic level may strongly affect child health by determining the quality of housing and nutrition and the ability to pay for medical care. The DHS surveys generally do not collect information on household income or wealth, and neither of the two surveys we utilized included such information. Thus, to represent the household's economic level we used principal components analysis to construct a linear index of possession of a radio, television, or refrigerator, and whether there was electricity in the dwelling (Filmer & Pritchett, 2001). We derived the weights for each index item from the principal components analysis, then summed the weighted item values and rescaled the index to range from 0 to 1.[3] Black children live in households with the fewest economic resources, and Whites and

[3]Principal components analysis is used to construct the index of economic resources because the series of indicators we would like to include as predictors are very highly intercorrelated,

Asians live in the wealthiest households. Black and Colored children in the 1998 sample were significantly better off, on average, than those in the 1987–89 sample, while Asian children's average standing did not change and the standing of White children was slightly, but significantly, lower, possibly reflecting a slight decrease in their relative advantage.

Living in a rural area in South Africa indicates limited access to educational and occupational opportunities, health-producing resources, and health care services and information. However, rural-to-urban migration also may be deleterious to infant health for Blacks, because many such migrants live in squatter settlements with inadequate warmth or hygiene. We measure the effect of place of residence via a typology formed by crossing mother's place of residence at age 12 (urban or rural) with her place of residence at the date of the interview (urban or rural). In all four racial groups, but particularly for Blacks and Coloreds, the proportion of lifetime rural residents was lower in the later survey, and for all but Whites the proportion of rural-to-urban migrants increased between the two survey periods. Unexpectedly, the 1998 data also show smaller proportions of lifetime urban residents among Blacks and Coloreds than do the 1987–89 data. This may reflect variations in sampling procedures in the 2 years; it is not possible to investigate this since there is no measure of type of childhood residence in corresponding census data.

Household sanitation is a marker both of the environmental conditions in which a child is raised and of the level of infrastructure development in a community. We distinguish categories that denote combinations of clean water (piped or bottled water versus other sources) and toilet facilities (flush toilet or latrine versus other facilities or none) available to the household. Black children are most likely to live in households with less-than-optimal sanitation conditions: in the 1987–89 sample, only about 60% lived in household with both clean water and a toilet, compared with 88% of Colored children, 99% of Asian children and 97% of White children. For Black and Colored children, there was a significant increase between the two survey periods in the likelihood of living in households with both clean water and a toilet.

Since community resources are known to affect child mortality (e.g., Sastry, 1996), we considered including community indicators of level of living, and did some exploratory analysis using measures derived from the 1985 and 1996 South African censuses. Ultimately, however, we dropped the community indicators because they produced results that were more confusing than enlightening. The main difficulties were, first, that the 1985 census includes only a few variables and, moreover, did not include the TVBC States, which means that we have no community-level information for a quarter of the Black population in the 1987–89 survey. Second, community poverty is highly correlated with household variables already in the model, particularly mother's education, the household economic level, and the sanitation measures.

(*footnote continued*)
causing statistical problems when we try to estimate models of infant mortality including each as a separate predictor.

Methods

For the analysis, we estimate logistic regression models of the odds of dying before the age of 1 year.[4] Using Stata version 8.0 SE software, we implemented these models while controlling for the clustering of multiple children born to the same mother by using the Huber–White, or "sandwich" estimator (StataCorp, 2003). The analysis is conducted using a pooled analytic sample that contains data from the 1987–89 and 1998 surveys, with sampling weights designed to make each sample representative of the South African population at the time of that survey. All models include a dichotomous indicator of period that distinguishes interviews conducted during the 1987–89 survey from those obtained in the 1998 survey. Results obtained from all models are presented as odds ratios, with *p*-values provided in parentheses. Model 1 estimates the odds of death before 1 year of age considering only mother's race, child's sex, and an indicator of period that divides children born to mothers interviewed in the 1987–89 survey and those born to mothers interviewed

[4]In preliminary analyses not reported here, we also explored parametric frailty models and shared frailty models, hazard models that deal with unmeasured heterogeneity, or frailty, that is introduced as an unobservable multiplicative effect on the hazard of death. Shared frailty models, in our case denoting children who shared the same mother, could be useful because it is likely that children born to the same mother are subject to more similar conditions than are children chosen at random. However, we were unable to implement shared frailty models using sample weights, which are necessary in our analysis. Furthermore, we compared a series of parametric survival models that incorporated shared frailty (children within mothers), individual-level frailty (at the child level), or no frailty component, and found that our results were not substantively different across these specifications. We also explored the use of parametric survival time models that can accommodate survey weights, comparing models specified with the exponential and Weibull distributions, and examining the proportional hazards and accelerated failure time metrics. Nonetheless, we found that logistic regression models produced substantively equivalent results to those obtained from the frailty and parametric survival time models, and therefore chose to report the results of the most parsimonious logistic regression models here.

in the 1998 survey.[5] Here our primary interest is in the effect of mother's racial group. In Model 2 we add indicators of socioeconomic characteristics—mother's years of education and household economic resources—to examine how much of the racial disparity in child mortality is accounted for by the differential distribution of these resources. In Model 3 we add measures of the conditions prevailing at the time of the birth and sociodemographic characteristics of the mother, including the child's birth order and preceding birth interval, mother's age, and her place of residence in childhood and at the time of the survey. Some of these covariates, such as place of residence, may explain pathways through which socioeconomic resources exert their effects. Model 4 adds information about household sanitation, which reflects both household environmental conditions and community-level infrastructure. We examine whether inclusion of sanitation indicators modifies the effects of household socioeconomic resources and sociodemographic characteristics of mothers and children. Our final Model 5 includes interaction terms between period (1987–89 survey interview versus 1998 survey interview) and key predictors whose effects may have changed over time: mother's racial group, mother's education, and household economic resources. In analyses not shown here, we also tested for interactions between mother's race and other key predictors, such as mother's education, household economic resources, and the current and former residence typology, to see if the effects of predictors varied by race. However, none of these interactions added significantly to the models, and they are not discussed here.

Results

The results of the analysis are shown in Table 2. The odds ratios show the net effect of a one-unit change in the independent variable on the odds of death in the first year of life. For categorical predictors, the odds ratios give the expected ratio of the odds for those in a particular category relative to those in the reference, or omitted, category. For example, in Model 1 the odds ratio for Whites is 0.149, which indicates that among children of the same sex and born in the same period, White infants are less than one-sixth as likely as Black infants to die before they reach 1 year of age. The figures in parentheses give the *p*-values associated with each odds ratio; thus, in Model 1 the odds ratio for infants in each of the Nonblack groups is significantly lower than for Black infants by conventional standards ($p<0.05$). Wald chi-square (χ^2) tests of the significance in the improvement of fit as we add successive variables in Models 2–5 are shown at the bottom of the table.

Model 1 shows a clear racial gradient in the risk of infant mortality. Net of children's sex, the likelihood of dying before age 1 is about one-sixth as high for White infants, less than one-third as high for Asian infants, and just under two-thirds as high for Colored infants, compared with the odds for Black infants. This gradient mirrors exactly the system of relative racial advantage institutionalized during the *apartheid* period. The change in these odds ratios in successive models makes clear, at least in part, how the racial gradient is created. Controlling for the sociodemographic characteristics of the household in subsequent models reduces the distinctions between Colored and Black infants to nonsignificance and reduces the odds ratios for Blacks relative to Whites. The magnitude of the difference between Blacks and Asians is reduced across the subsequent models, but is still statistically significant through Model 4. Infant mortality risk is almost one-third greater for male than for female infants, a pattern also found in other settings that do not display gender-discriminatory allocation of resources and care for children (Waldron, 1987). Finally, there is no significant difference in infant mortality risk between the late- and post-*apartheid* periods in our models, which means that hoped for reductions in infant mortality due to greater investments in population health had not materialized for those born between 1993 and 1998. Of course, since the regime change occurred in April 1994, it could be the case that too little time had elapsed for improvements in the health infrastructure or the quality of housing—which, after all, take some time to implement—to have had much effect. The lack of a reduction in overall mortality risk between the two surveys suggests that without the positive changes in the distribution of health-enhancing resources evident from the descriptive information in Table 1, there may have even been an increase in infant mortality.

Model 2 adds mother's years of schooling and an index of household economic resources, both of which have an impact on infant mortality. For example, if the average education of Black women matched that of White women (a 5.3 year difference in 1987–89), the odds of mortality for their infants would be reduced by about 14% ($=1-0.973^{5.3}$), net of all other factors. Similarly, the risk of infant mortality for those living in

[5]The *apartheid* regime formally ended with the election held in April 1994. Since it is difficult to pinpoint when legislative changes surrounding the regime change would begin to affect the life chances of individuals, we think a reasonable cutting point is to distinguish between those born clearly before the transition (1982–89) and reported by mothers in the 1987–89 survey and those born between 1993 and 1998, reported by mothers in the second survey. We would have preferred to distinguish single years, to permit a more fine-grained analysis of trends, but the relatively small number of deaths in any given year made this impossible.

Table 2
Odds ratios for death in first year of life

	Model 1	Model 2	Model 3	Model 4	Model 5
Mother's race (black omitted)					
Colored	0.611	0.737	0.767	0.766	0.786
	(0.002)	(0.075)	(0.128)	(0.125)	(0.220)
Asian	0.300	0.496	0.495	0.489	0.605
	(<0.001)	(0.030)	(0.030)	(0.028)	(0.138)
White	0.149	0.271	0.273	0.267	0.206
	(<0.001)	(0.016)	(0.017)	(0.015)	(0.008)
Child's sex male	1.31	1.32	1.32	1.32	1.32
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Survey year 1998	0.859	0.981	0.989	0.979	0.776
	(0.158)	(0.861)	(0.918)	(0.853)	(0.280)
Mother's years of education		0.973	0.979	0.982	0.980
		(0.028)	(0.106)	(0.197)	(0.185)
Household economic resources		0.534	0.520	0.532	0.471
		(<0.001)	(<0.001)	(0.001)	(0.001)
Mother 35 years or older at birth			1.39	1.40	1.40
			(0.011)	(0.008)	(0.008)
Birth order/previous birth interval (1st birth omitted)					
2nd, ⩽36 months			1.07	1.06	1.06
			(0.656)	(0.691)	(0.683)
2nd, >36 months			0.728	0.729	0.727
			(0.049)	(0.050)	(0.048)
3rd+, ⩽36 months			1.19	1.18	1.19
			(0.173)	(0.195)	(0.179)
3rd+, >36 months			0.715	0.712	0.718
			(0.020)	(0.018)	(0.021)
Missing			1.22	1.22	1.21
			(0.731)	(0.725)	(0.694)
Mother's place of residence: childhood and current (lifetime urban omitted)					
Rural-to-urban migrant			1.08	1.09	1.08
			(0.675)	(0.622)	(0.665)
Urban-to-rural migrant			0.496	0.496	0.487
			(0.150)	(0.021)	(0.018)
Lifetime rural			0.958	0.93	0.916
			(0.735)	(0.580)	(0.506)
Missing			0.427	0.464	0.467
			(0.408)	(0.454)	(0.457)
Household sanitation (clean water, have toilet omitted)					
Clean water, no toilet				1.13	1.13
				(0.490)	(0.477)
No clean water, have toilet				0.978	0.979
				(0.855)	(0.122)
No clean water, no toilet				1.26	1.29
				(0.130)	(0.094)
Missing				0.447	0.468
				(0.179)	(0.206)
Survey year 1998 × Mother's race Colored					0.894
					(0.785)
Survey year 1998 × Mother's race Asian					0.419
					(0.419)
Survey year 1998 × Mother's race White					3.09
					(0.316)

Table 2 (*continued*)

	Model 1	Model 2	Model 3	Model 4	Model 5
Survey year 1998 × Mother's years of education					1.01 (0.718)
Survey year 1998 × Household economic resources					1.48 (0.268)
Model χ^2	44.7 (<0.001)	75.9 (<0.001)	103.3 (<0.001)	111.9 (<0.001)	113.3 (<0.001)
Wald tests of groups of additional covariates	—	26.4 (<0.001)	29.3 (0.001)	4.93 (0.295)	4.20 (0.520)

Note: *p*-values reported in parentheses. Estimates are adjusted for clustering of children born to the same mother.

households with the highest level of economic resources is close to half of that for infants living in households with the lowest level of economic resources. Since our economic resources measure does a better job of differentiating at the low end of the distribution (fully 28% have the highest score on the scale), the coefficient is best interpreted as indicating the increased odds of infant mortality experienced by the economically most marginal portion of the population relative to those with an adequate standard of living. Including measures of mother's education and the household economic level substantially reduces the racial differential in mortality: the magnitude of differences for all comparisons is reduced and the Colored–Black and White–Black ratios become marginally significant.

Model 3 adds mother's age, the birth order and birth interval, and mother's place of residence/migration experience. Infants born to mothers 35 or older are at greater risk of mortality, and second or third and higher-order births that took place more than 36 months after the previous birth have a significantly lower risk of mortality than first births. Somewhat unexpectedly, the children of women who lived in an urban place in childhood but currently reside in the countryside have a significantly lower risk of death than those whose mothers always lived in urban areas. Urban to rural migrants are a fairly small group of women, comprised heavily of Whites, who may merit future examination. None of the coefficients from Model 2 is dramatically changed by introduction of the additional variables in Model 3, though the marginal significance associated with Colored race and mother's education disappears, and the effect of mother's education no longer reaches statistical significance.

Model 4 adds indicators of the quality of sanitary facilities; there are no significant effects of different categories of sanitation, though it appears that children without clean water or modern toilets may be worst off. Controlling for plumbing hardly changes the other coefficients from Model 3, and the Wald test shows that the group of indicators for sanitary facilities does not add significantly to the model fit. Model 5 includes interactions terms to test for difference in the effects of predictors between the earlier and later period. We cannot reject the null hypothesis that the interaction terms are collectively equal to zero, suggesting that the way socioeconomic resources and demographic characteristics influence the risk of infant mortality did not change in the early post-apartheid period.

Discussion

This analysis provides an accounting of the basic trends in infant mortality over a period of critical change in the politics of racial equality in South Africa. We find no evidence for reduced overall risk of infant death in the early post-*apartheid* years, despite policy and action directed toward this goal. Though efforts by the new government appear to have led to some reductions in racial disparities in levels of living, Black children born between 1993 and 1998 continued to have poorer living conditions, resources, and survival prospects than others in their first year of life. The very substantial racial gradient in the risk of mortality (more than six times greater for Blacks than for Whites, with the other groups falling in between) is partly but not completely explained by racial differences in mother's education and household economic resources. Demographic factors also continue to influence mortality, specifically the child's sex, mother's age, and the timing and number of births to the mother. Controlling for these factors eliminates significant mortality risk differences between Black and Colored infants, while the Black–White ratio falls to between 3 and 4 to 1.

Independent evidence supports our findings for the overall trend in infant mortality over this period.

Based on a model used to estimate the impact of the HIV/AIDS epidemic in South Africa, overall infant mortality may have been falling slightly until about 1995, then appears to have risen and, by the end of the decade, to have surpassed levels of mortality in the early 1990s (Dorrington et al., 2002). The present analysis adds to our understanding of the sociodemographic characteristics that continue to be key determinants of this trend and that underlie racial disparities in mortality, despite recent changes in the cause-of-death profile. However, limitations of the data used here mean that some of the measures we include are not optimal. The indicator of household economic resources used in this analysis is only a proxy for actual economic resources that could influence children's health and mortality, and does not make fine distinctions between individual households, especially at the higher end of the distribution. More comprehensive measures of income or wealth might help to explain the remaining Black–White disparity. In addition, we have no direct measures of the availability of health services or women's health behaviors, which are important proximate determinants of infant health and could enrich future studies. Obviously, cause-of-death information would be useful for determining the changing profile of needs for reducing infant mortality in South Africa, but obtaining accurate information is difficult, even in a household interview survey, because of the stigma attached to an HIV/AIDS-related death. Continued attention to the basic demographic and socioeconomic risk factors emphasized in the present analysis, which influence the survival probabilities of all sick infants, remains essential.

It appears that policy and programs to encourage racial parity in the conditions surrounding successful pregnancies and early childhoods may require more time to exert their effects, but potential positive changes face a dire challenge in the contemporary HIV/AIDS epidemic in South Africa. Among pregnant South African women attending public health clinics for antenatal care, the prevalence of HIV has increased from less than 1% in 1990 to 26.5% in 2001 (Department of Health, 2003). Based on a comprehensive model of the HIV/AIDS epidemic in South Africa, incidence of HIV may already have peaked and begun to decrease; however, the number of people dying from AIDS each year has only begun to rise (Dorrington et al., 2002). Without interventions to reduce mortality from the epidemic, deaths will peak in about 2010, accompanied and followed by an increase in the number of maternal orphans under the age of 15. This means that even among the estimated 55–85% children who do not contract HIV through vertical transmission (in vitro, at birth, or through breastfeeding), many will lose a primary caretaker, reducing their survival chances (Walker, Schwartlander, & Bryce, 2002).

Evidence collected in a household survey in 2002 found that among children 2–18 years of age, HIV prevalence was 5.4%, and the rate of maternal orphanhood was 3.3% (Brookes et al., 2004). While these figures are high, they provide some support for our assumption that the trend in overall mortality we observed from 1987 to 1998 was not greatly influenced by HIV/AIDS. The likely impact in the future, however, could be enormous. It has been projected that AIDS will account for a 100% increase in child mortality from an anticipated 48.5 deaths (without AIDS) to almost 100 deaths (including AIDS) per 1000 children in 2010 (United Nations Development Programme, 1998). Evidence from South Africa (Smart, 2000) and Rwanda (Spira et al., 1999) suggests that many infected children will show signs of HIV disease or AIDS in the first year of life, but most will survive at least to age 2. Therefore, greater effects of the epidemic are likely to be apparent in the trajectory of under-5 mortality rates. Estimates of HIV-attributable death rates by age 5, corrected for competing causes of mortality, ranged from 10.8 to 26.2 in 1999 and were projected to rise (Walker et al., 2002). Further, these estimates are known to be too low, as they did not account for indirect effects on child health that result from HIV in parents, families, and communities.

To keep pace with the projected increase in HIV/AIDS mortality, both among infants and children themselves and their primary caretakers, offsetting improvements to bolster infant health will have to rise dramatically, a very tall order for a government already economically strapped by the need to reduce the huge racial disparities in the level of living that are the legacy of a half century of *apartheid* and three centuries of less formal but equally pronounced differential advantage. As in other societies, but even more so in South Africa (Treiman, McKeever, & Burgard, 1998), socioeconomic position is passed from parents to their children, which means that even surviving children of the severely disadvantaged, who are mainly Black, are likely to persist in their disadvantage, inheriting unhealthy conditions for future reproduction and child rearing. Families living in the poorest regions, which would benefit most from relocation to areas with better infrastructure and economic opportunities, are least able to escape their current conditions. The efforts of the new government to improve health by increasing the general level of living and preventive health care in the mid-1990s will continue to be important strategies for reducing the transmission of social disadvantage, but the strain on the health service is already high (Coleman & Wilkinson, 1997; Gilks, Haran, & Wilkinson, 1996). Recent actions taken by the state to improve infant and child survival are targeting HIV/AIDS (Romani & Anderson, 2002), but until affordable antiretroviral therapies or a vaccine are available, there is an urgent

need to address underlying social and structural determinants of HIV/AIDS through sound policies and programs (Poundstone, Strathdee, & Celentano, 2004), or social and racial disparities are likely to grow (United Nations Development Programme South Africa, 2003).

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References

Abrahams, N., Jewkes, R., & Mvo, Z. (2001). Health care-seeking practices of pregnant women and the role of the Midwife in Cape Town, South Africa. *Journal of Midwifery and Women's Health*, *46*(4), 240–247.

Andersson, N., & Marks, S. (1988). Apartheid and health in the 1980s. *Social Science & Medicine*, *27*, 667–681.

Bachmann, M., London, L., & Barron, P. (1996). Infant mortality rate inequities in the Western Cape Province of South Africa. *International Journal of Epidemiology*, *25*(5), 966–972.

Benetar, S. R., Folb, P. I., van Niekerk, J. P., Bothwell, T. H., Ncayiyana, D. J., Jacobs, M., et al. (1997). Country profile: South Africa. *Lancet*, *349*(9064), 1537–1545.

Bloom, G., & McIntyre, D. (1998). Towards equity in health in an unequal society. *Social Science & Medicine*, *47*(10), 1529–1538.

Botha, J. L., & Bradshaw, D. (1985). African vital statistics—A black hole? *South African Medical Journal*, *67*, 977–981.

Bourne, D. E., Rip, M. R., & Woods, D. L. (1988). Characteristics of infant morality in the RSA 1929–1983. Part II. Causes of death among white and coloured infants. *South African Medical Journal*, *73*(4), 230–232.

Brookes, H., Shisana, O., & Richter, L. (2004). *The national household HIV prevalence and risk survey of South African children*. Cape Town: HSRC Publishers.

Buchmann, E. J., Crofton Briggs, I. G., & McIntyre, J. A. (1992). Previous birth outcome of antenatal clinic attenders in Northern KwaZulu—Perinatal and infant mortality rates. *South African Medical Journal*, *81*(8), 419–421.

Caldwell, J. C., & Caldwell, P. (1993). The South African fertility decline. *Population and Development Review*, *19*(2), 225–262.

Cleland, J. G. (1990). Maternal education and child survival: Further evidence and explorations. In J. G. Caldwell, S. Findley, P. Caldwell, G. Santow, W. Cosford, J. Braid, & D. Broers-Freeman (Eds.), *What we know about health transition: The cultural, social, and behavioral determinants of health* (pp. 400–419). Canberra: Australian National University.

Cleland, J. G., & Van Ginneken, J. K. (1988). Maternal education and child survival in developing countries: The search for pathways of influence. *Social Science & Medicine*, *27*(12), 1357–1368.

Coleman, R. L., & Wilkinson, D. (1997). Increasing HIV prevalence in a rural district of South Africa from 1992 through 1995. *Journal of Acquired Immune Deficiency Syndromes and Human Retrovirology*, *16*(1), 50–53.

Davenport, T. R. H. (1987). *South Africa: A modern history* (3rd ed). Johannesburg: Macmillan.

Department of Health. (2003). *National HIV and syphilis sero-prevalence survey in South Africa: 2002*. Pretoria: Directorate: Health Systems Research, Research Coordination and Epidemiology.

Department of Health of South Africa and Macro International (SADOH and MI). (2003). *South African demographic and health survey 1998: Full report*. Pretoria and Calverton, MD: SADOH and MI.

Desmond, C. (Ed.). (1998). Editorial. *Children First: A journal on issues affecting children and their careers*, *2*(19).

Dorrington, R., Bradshaw, D., & Budlender, D. (2002). *HIV/AIDS profile in the provinces of South Africa*. Cape Town: Centre for Actuarial Research, Medical Research Council and the Actuarial Society of South Africa.

Duncan, N. (1997). Malnutrition and childhood development. In C. de la Rey, N. Duncan, T. Shefer, & A. Van Niekerk (Eds.), *Contemporary issues in human development: A South African focus*. Durban: ITP.

Filmer, D., & Pritchett, L. H. (2001). Estimating wealth effects without expenditure data—Or tears: An application to educational enrollments in States of India. *Demography*, *38*, 115–132.

Gilks, C. F., Haran, D., & Wilkinson, D. (1996). Coping with the impact of the HIV epidemic: The Hlabisa–Liverpool link. *South African Medical Journal*, *86*, 1077–1078.

Haffejee, I. E. (1995). Child health in South Africa—Past, present and future. *Global Child Health News and Review*, *3*(1), 18.

Herman, A. A., & Wyndham, C. H. (1985). Changes in infant mortality rates among whites, coloureds and urban blacks in the RSA over the period 1970–1983. *South African Medical Journal*, *68*(4), 215–218.

Kaufman, C. E. (1997). *1987–98 South african demographic and health survey: Methodology and data quality, Report No. 97–395*. Ann Arbor: University of Michigan Population Studies Center.

Kaufman, C. E. (1998). Contraceptive use in South Africa under apartheid. *Demography*, *35*(4), 421–434.

Koumans, E. H. (1992). Infant and child mortality in the Elim district, northern Transvaal, 1976–1986, and a comparison of trends. *South African Medical Journal*, *81*(4), 202–205.

Lockhat, R., & Van Niekerk, A. (2000). South African children: A history of adversity, violence and trauma. *Ethnicity and Health*, *5*(3/4), 291–302.

Louw, H. H., Khan, M. B., Woods, D. L., Power, M., & Thompson, M. C. (1995). Perinatal mortality in the Cape Province, 1989–1991. *South African Medical Journal*, *85*(5), 352–355.

Molteno, C. D., & Kibel, M. A. (1989). Postneonatal mortality in the matroosberg divisional council area of the Cape Western health region. *South African Medical Journal*, *75*(12), 575–578.

Molteno, C. D., Ress, R., & Kibel, M. A. (1989). Early childhood mortality in Cape Town. *South African Medical Journal*, *75*(12), 570–574.

Nannan, N., Bradshaw, D., Mazur, R., & Maphumulo, S. (1998). What is the infant mortality rate in South Africa? The need for improved data. *South African Medical Journal*, *88*(12), 1583–1587.

National Institute for Economic Policy. (1996). *Children, poverty, and disparity reduction: Towards fulfilling the rights of South Africa's children*. A report commissioned by the Ministry in the Office of the President: Reconstruction and Development Programme.

Pebley, A. R., & Stupp, P. W. (1987). Reproductive patterns and child mortality in Guatemala. *Demography*, *24*, 43–60.

Platzky, L., & Walker, C. (1985). *The surplus people: Forced removals in South Africa*. Johannesburg: Ravan Press.

Poundstone, K. E., Strathdee, S. A., & Celentano, D. D. (2004). The social epidemiology of human immunodeficiency virus/acquired immunodeficiency syndrome. *Epidemiologic Reviews*, *26*, 22–35.

Ramashia, R. (1998). Address by the president of the SA NGO Coalition. *National Speak Out on Poverty Hearings*.

Ramphele, M. A., & Heap, M. (1991). Health status of hostel dweller. Part II. Infant mortality and prevalence of diabetes, hypertension and syphilis among adults. *South African Medical Journal*, *79*(12), 702–705.

Rip, M. R., Keen, C. S., & Kibel, M. A. (1986). A medical geography of perinatal mortality in metropolitan Cape Town. *South African Medical Journal*, *70*(7), 399–403.

Rip, M. R., Bourne, D. E., & Woods, D. L. (1989a). The geographical variation in neonatal and post-neonatal mortality in South Africa, 1978–1982. *South African Medical Journal*, *76*(2), 49–52.

Rip, M. R., Bourne, D. E., & Woods, D. L. (1989b). The spatial variation of mortality among children under 5 years of age in South Africa. *South African Medical Journal*, *75*(12), 565–570.

Romani, J. H., & Anderson, B. A. (2002). *Development, health, and the environment: Factors influencing infant and child survival in South Africa*. University of Michigan: Population Studies Center Research Report No. 02-525.

SAIRR. (1995). *Fast facts. State of the nation report*. Braamfontein: SAIRR.

SAIRR. (1996). *Fast facts: Household and child poverty*. Braamfontein: SAIRR.

Sastry, N. (1996). Community characteristics, individual and household attributes, and child survival in Brazil. *Demography*, *33*, 211–229.

Sastry, N. (1997). Family-level Clustering of childhood mortality risk in Northeast Brazil. *Population Studies*, *51*(3), 245–261.

Smart, R. (2000). *Children living with HIV/AIDS in South Africa—A rapid appraisal*. Johannesburg: Save the Children UK.

Spira, R., Lepage, P., Msellati, P., Van de Perre, P., Leroy, V., Simonton, A., Karita, E., & Dabis, F. (1999). Natural history of the human immunodeficiency virus type 1 infection in children: A five-year prospective study in Rwanda. *Pediatrics*, *104*(5), e56.

StataCorp. (2003). *Stata statistical software: Release 8.0*. College Station, TX: Stata Corporation.

Statistics South Africa. (2000). *Measuring poverty in South Africa*. Pretoria: Statistics South Africa.

Statistics South Africa. (2003). *Census in brief, 2001 (Report No. 03-02-03)*. Pretoria, South Africa: Statistics South Africa.

Treiman, D. J., McKeever, M., & Fodor, E. (1996). Racial differences in occupational status and income in South Africa, 1980 and 1991. *Demography*, *33*(1), 111–132.

Treiman, D. J., McKeever, M., & Burgard, S. (1998). Racial Differences in Status Attainment in South Africa. Paper presented at the *World Congress of Sociology*, Montreal, Canada, July 26–August 1.

United Nations Development Programme. (1998). *HIV/AIDS, human development, South Africa*. Pretoria: United Nations Development Programme.

United Nations Development Programme South Africa. (2003). *South Africa human development Report 2003*. Cape Town, South Africa: Oxford University Press.

Waldron, I. (1987). Patterns and causes of excess female mortality among children in developing countries. *World Health Statistics Report*, *40*, 194–210.

Walker, N., Schwartlander, B., & Bryce, J. (2002). Meeting international goals in child survival and HIV/AIDS. *The Lancet*, *360*(July 27), 284–289.

World Bank. (2000). *World development indicators*. Washington, DC: World Bank.